Antioxidant and Physiological Responses to Ginger and Turmeric in Cadmium-Treated Female Rats: Implications for Oxidative Stress and Weight Modulation

**Abstract**

Aim:

This study investigated the protective effects of turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*)—individually and in combination—on cadmium chloride (CdCl₂)-induced oxidative stress and body weight alterations in female Wistar rats.

Methods:

Thirty female albino Wistar rats were randomly assigned into five groups (n = 6): control, cadmium-only (5 mg/kg, i.p.), cadmium + turmeric (200 mg/kg), cadmium + ginger (200 mg/kg), and cadmium + turmeric + ginger (200 mg/kg each). Treatments were administered for 15 consecutive days. Body weight changes were recorded. Serum antioxidant parameters—including superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and malondialdehyde (MDA)—were assayed using standard spectrophotometric methods.

Results**:**

Cadmium administration significantly reduced body weight and antioxidant enzyme activities (SOD, CAT) while increasing MDA levels (*p*< 0.05), indicating oxidative stress. Co-treatment with turmeric and ginger, especially in combination, restored antioxidant enzyme activity and lowered MDA levels toward control values. Turmeric alone preserved body weight, while ginger-treated rats showed moderate weight loss. GPx activity exhibited a non-significant upward trend in treatment groups.

Conclusion**:**

Turmeric and ginger mitigate cadmium-induced oxidative damage and weight loss through their antioxidant properties. The combination therapy demonstrated synergistic efficacy, suggesting potential for natural product-based interventions in cadmium toxicity and oxidative stress-related disorders. Further studies are recommended to elucidate underlying mechanisms and optimize dosage strategies.

**Keyword:** *Cadmium toxicity, Oxidative stress, Antioxidant enzymes, Turmeric (Curcuma longa), Ginger (Zingiber officinale), Body weight modulation, Lipid peroxidation*

1. **Introduction**

Cadmium (Cd) is a toxic heavy metal and an established environmental pollutant that poses a serious threat to human and animal health (Genchi *et al*., 2020). It is widely distributed in the environment due to industrial emissions, contaminated water, fertilizers, and cigarette smoke (Sharma*et al.*, 2023). Chronic exposure to cadmium, even at low doses, is associated with bioaccumulation in soft tissues such as the liver, kidneys, and reproductive organs (Peana *et al*., 2022). One of the most detrimental effects of cadmium toxicity is its ability to induce oxidative stress, characterized by the overproduction of reactive oxygen species (ROS), lipid peroxidation, and depletion of antioxidant defense systems (Branca *et al*., 2020).

Cadmium-induced oxidative stress disrupts cellular redox balance and impairs key antioxidant enzymes including superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx), while simultaneously increasing levels of malondialdehyde (MDA), a biomarker of lipid peroxidation (Li *et al.*, 2016; Wang *et al*., 2011).. Furthermore, cadmium exposure has been associated with weight loss, impaired metabolic activity, and general physiological deterioration (Zhu *et al*., 2024).

Recent scientific interest has turned toward the use of natural products and phytochemicals as protective agents against heavy metal toxicity (Isamoh et al., 2024; Umoh *et al.*, 2024). Among these, turmeric (Curcuma longa) and ginger (Zingiber officinale) have been recognized for their potent antioxidant, anti-inflammatory, and detoxifying properties (Ramadan *et al*., 2011; Zhou *et al*., 2022). Curcumin, the active constituent of turmeric, has been shown to modulate oxidative pathways and restore redox balance, while gingerol in ginger exhibits strong radical-scavenging activity and supports cellular antioxidant responses (Sharifi-Rad *et al.*, 2020; Ayustaningwarno *et al*., 2024).

Although prior studies have demonstrated the individual antioxidative effects of turmeric and ginger in various toxicological models, few have investigated their combined efficacy, particularly in cadmium-induced models involving both biochemical (oxidative stress) and physiological (body weight) parameters.

Cadmium chloride (CdCl₂) is a well-known environmental toxicant whose toxic effects are primarily mediated through oxidative stress pathways (Qu & Zheng, 2024). When absorbed into biological systems, cadmium interferes with essential cellular functions by generating reactive oxygen species (ROS) and inhibiting the antioxidant defense mechanisms of cells (Unsal *et al*., 2020). These changes contribute to cellular damage, lipid peroxidation, enzyme inactivation, and metabolic dysfunction (Isamoh*et al.*, 2024). One of the hallmark consequences of cadmium toxicity is the disturbance in antioxidant homeostasis, often observed as decreased activities of SOD, CAT, and GPx, alongside elevated MDA levels (Taysı, 2024).

Cadmium exposure has also been shown to cause a decline in body weight, likely due to anorexia, gastrointestinal disturbances, and oxidative injury to metabolic tissues (Green*et al.,* 2018). Monitoring body weight alongside oxidative markers provides a reliable indicator of systemic toxicity and the potential restorative effects of therapeutic interventions.

In the search for safe and effective antidotes to cadmium toxicity, natural plant-based antioxidants have received considerable attention. Turmericand ginger, two widely used culinary and medicinal rhizomes, contain phytochemicals such as curcumin, gingerols, and shogaols, which are known for their free radical scavenging, enzyme-modulating, and anti-inflammatoryeffects (Ajanaku*et al*., 2022; Ballester*et al.*, 2023). These compounds have been shown to enhance antioxidant enzyme activity, reduce lipid peroxidation, and mitigate tissue damage in chemically induced toxicity models.

However, the combined protective potentialof turmeric and ginger against cadmium chloride-induced alterations in both oxidative stress biomarkersand body weight dynamics has not been fully explored. This study, therefore, seeks to investigate the antioxidant and body weight modulatory effectsof ginger and turmeric in cadmium-treated female rats, using a combination of biochemical and morphological assessmentsto evaluate their restorative efficacy.

**2. Materials and Methods**

2.1. Experimental Animals

Twenty-five (25) female albino Wistar rats (120–180 g) were obtained from the animal house, College of Medical Sciences, University of Calabar. The animals were housed in wooden cages with wire mesh covers under standard laboratory conditions: room temperature (25 ± 2 °C), relative humidity (50 ± 5%), and a 12-hour light/dark cycle. They were fed standard pellet diet and water *ad libitum.* Cages were lined with sawdust (sourced from Akim Timber Market, Calabar), which was changed daily to maintain hygiene and prevent infection. Animals were acclimatized for 14 days prior to the experiment. All procedures were approved by the Faculty Animal Research Ethics Committee, Faculty of Basic Medical Sciences, University of Calabar (Approval No: 217ANA2323).

2.2. Chemicals and Plant Extracts

Cadmium chloride (CdCl₂, analytical grade) was purchased from Henan Alfa Chemical Co. Ltd, China, and freshly prepared in distilled water at a dose of 5 mg/kg body weight. Fresh rhizomes of ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) were obtained from Utugwang Market, Obudu LGA, Cross River State, and authenticated by Mr. Effa A. Effa (Department of Botany, University of Calabar). Voucher numbers Bot/Herb/UCC/178 (ginger) and Bot/Herb/UCC/177 (turmeric) were assigned.

The rhizomes were washed, sliced, air-dried at 40 °C, and ground into powder. Aqueous extracts were obtained by soaking 100 g of the powdered material in 1 L distilled water for 48 hours. The mixture was filtered and concentrated under reduced pressure at 45 °C using a rotary evaporator, followed by drying in a vacuum water bath to yield 50 g of each crude extract. Extracts were stored at 4 °C and reconstituted in distilled water before use.

Commercial assay kits for CAT, SOD, GPx, and MDA were obtained from Sigma-Aldrich.

2.3. Experimental Design

The 30 rats were randomly divided into five groups (n = 6 per group) as follows:

Group I (Control): Distilled water only

Group II (CdCl₂ only): Cadmium chloride (5 mg/kg)

Group III (CdCl₂ + Turmeric): CdCl₂ (5 mg/kg) + Turmeric extract (200 mg/kg)

Group IV (CdCl₂ + Ginger): CdCl₂ (5 mg/kg) + Ginger extract (200 mg/kg)

Group V (CdCl₂ + Turmeric + Ginger): CdCl₂ (5 mg/kg) + Turmeric (200 mg/kg) + Ginger (200 mg/kg)

Ginger and turmeric extracts were administered orally via orogastric tube once daily at 8:00 AM, while cadmium was administered intraperitoneally, both for 15 consecutive days.

2.4. Body Weight Measurement

The weight of each rat was measured and recorded just prior to the commencement of administration and before termination of experiment using an electronic weighing balance using a digital weighing balance. The percentage change in body weight was calculated to evaluate the impact of cadmium and the effect of treatment.

2.5. Sample Collection

Following 15 days of treatment, animals were fasted overnight and sacrificed on Day 16 under light anesthesia using 0.2 mL ketamine (i.p.), as described by Anyiom *et al*. (2024). Blood samples were collected via cardiac puncture, allowed to clot, and centrifuged at 3000 rpm for 15 minutes. The resulting serum was separated and stored at −20 °C for further biochemical analyses.

2.6. Biochemical Assays

Superoxide Dismutase (SOD) Activity

SOD activity was assayed by its ability to inhibit the auto-oxidation of epinephrine, as described by Sun and Zigman (1978). The reaction mixture contained 0.05 M sodium carbonate buffer (pH 10.2), sample, and epinephrine in 0.005 N HCl. Absorbance was read at 480 nm over 5 minutes. Enzyme activity was calculated using a molar extinction coefficient (ε) of 4020 M⁻¹cm⁻¹.

Catalase (CAT) Activity

CAT activity was determined according to Sinha (1972) by measuring the decomposition of hydrogen peroxide (H₂O₂). The assay mixture included phosphate buffer (pH 7.0), sample, and 2M H₂O₂. The reaction was stopped using dichromate-acetic acid reagent, and absorbance was read at 620 nm. Results were expressed as µmol of H₂O₂ decomposed per minute per mg protein using ε = 40 M⁻¹cm⁻¹.

Glutathione Peroxidase (GPx) Activity

GPx activity was measured following the method of Rotruck *et al.* (1973). The reaction mixture contained Tris buffer, EDTA, sodium azide, sample, GSH, and H₂O₂, and was incubated at 37°C for 10 minutes. The reaction was stopped with TCA and centrifuged. GPx activity was expressed as µg of GSH consumed per minute per mg protein.

Lipid Peroxidation (MDA Levels)

Malondialdehyde (MDA), an index of lipid peroxidation, was determined using the Buege and Aust (1978) method. The sample was mixed with TCA-TBA-HCl reagent, boiled at 100°C for 15 minutes, and centrifuged. The absorbance of the supernatant was read at 532 nm. MDA concentration was calculated using ε = 1.56 × 10⁵ M⁻¹cm⁻¹.

All enzyme activities were normalized to total protein content and expressed in appropriate units such as micromoles per milliliter per milligram protein (µmol/ml/mg protein).

2.7. Statistical Analysis

Data were analyzed using statistical package for social sciences (SPSS) version 26.0 for windows. Results were expressed as mean ± standard error of the mean (SEM). One-way analysis of variance (ANOVA) followed by Tukey’s multiple comparison test was used to determine statistical significance. A p-value less than 0.05 (*p*< 0.05) was considered statistically significant.

**3.1 Results**

3.1 Body Weight Changes

Body weight changes varied across the experimental groups (Fig. 1, Table 1). The control group (A) showed a progressive but non-significant increase in weight. In contrast, the cadmium-only group (B) exhibited a significant decrease in body weight from 138.68 ± 9.20 g to 124.36 ± 7.60 g (*p*< 0.05), indicating cadmium-induced weight loss.

Co-treatment with ginger and turmeric (Group C) led to a slight, non-significant weight reduction (150.72 ± 12.38 g to 143.68 ± 13.95 g), while ginger alone (Group D) caused a significant drop from 148.44 ± 6.01 g to 132.14 ± 7.43 g (*p*< 0.05). The turmeric-only group (E) showed stable body weight (147.40 ± 3.15 g to 147.52 ± 3.34 g), with no significant change.

Figure 1. Body Weight Changes in Experimental Groups

**Key:**

**NC=Normal control**

**Cd= Cadmium**

**G&T= Ginger and turmeric**

**Gr=Ginger**

**Tc=Turmeric**

Figure 1. Effect of cadmium and treatment with ginger and/or turmeric on body weight of rats. Data are presented as mean ± standard error (SE), n = 6 per group. Cadmium exposure (Group B) caused a significant reduction in body weight compared to the control group (p < 0.05). Co-administration with turmeric (Group E) stabilized body weight, while ginger alone (Group D) resulted in significant weight loss. The combination of ginger and turmeric (Group C) showed mild, non-significant weight reduction.

3.2 Antioxidant Assay

3.2.1 Superoxide Dismutase (SOD)

Group B (Cd-only) had significantly reduced SOD levels (29.79 ± 1.09) compared to the control Group A (44.62 ± 2.68, p < 0.05). Groups C, D, and E (ginger + turmeric, ginger only, turmeric only) showed improved SOD levels (34.91 ± 3.34, 33.13 ± 3.52, 31.26 ± 1.50, respectively), though not statistically significant compared to Group B.

Figure 2: Superoxide Dismutase (SOD) Levels in Experimental Groups

Figure 2. SOD activity across treatment groups. Values are mean ± SE (n = 6). Cadmium significantly reduced SOD levels compared to control (p < 0.05), while ginger and turmeric treatments improved SOD activity.

3.2.2 Catalase (CAT)

Group A had significantly higher CAT activity (48.48 ± 2.56) than Group B (27.77 ± 2.12) and Group D (32.89 ± 1.41). Groups C (36.97 ± 3.29) and E (33.41 ± 3.49) showed no significant difference from control.

Figure 3:Catalase(CAT)ActivityinExperimentalGroups

Figure 3. Catalase activity across groups. Control group showed significantly higher CAT levels compared to cadmium and ginger-only groups (p<0.05). Combined treatments moderately improved CAT activity.

3.2.3 Malondialdehyde (MDA)

Cadmium exposure (Group B) significantly increased MDA levels (7.10 ± 0.53) vs. control (4.09 ± 0.06). Groups C, D, and E had lower MDA values (4.18 ± 0.10, 4.27 ± 0.06, 4.18 ± 0.10) with no significant difference from Group A.

Figure 4: Malondialdehyde (MDA) Levels in Experimental Groups

Figure 4. MDA levels in serum. Cadmium significantly elevated lipid peroxidation (p<0.05). Co-treatment with ginger and /or turmeric reduced MDA levels to near control.

3.2.4 Glutathione Peroxidase (GPx)

Group B showed a slight, non-significant decrease in GPx (3.74 ± 0.35) vs. control (4.43 ± 0.15). Groups C, D, and E (3.99–3.86) did not differ significantly from either the cadmium or control group.

Figure 5 : Glutathione Peroxidase (GPx) Activity in Experimental Groups

Figure 5. GPx activity across groups. Slight decrease in GPx was observed in the cadmium group, but changes were not statistically significant across all groups.

**4. Discussion & Conclusion**

**4.1 Discussion**

Cadmium (Cd), a pervasive environmental toxicant, is widely acknowledged for its deleterious effects on biological systems, particularly through the generation of reactive oxygen species (ROS), which disrupt cellular redox balance and damage vital biomolecules (Peana *et al.*, 2022; Genchi *et al*., 2020). In the current study, cadmium exposure significantly altered oxidative stress markers and induced weight loss, which aligns with previous observations that chronic cadmium intoxication leads to systemic toxicity marked by increased lipid peroxidation, enzyme inactivation, and impaired metabolic regulation (Branca *et al*., 2020; Zhu *et al.*, 2024).

In the cadmium-only group, there was a marked reduction in the activities of endogenous antioxidant enzymes—SOD, CAT, and GPx—alongside a significant elevation in MDA levels, a key biomarker of lipid peroxidation. These findings corroborate the mechanistic understanding that cadmium depletes the antioxidant defense system while simultaneously triggering peroxidative membrane damage (Taysı, 2024; Wang *et al.*, 2011).

Conversely, administration of turmeric and ginger extracts, both individually and in combination, led to improved antioxidant profiles and partial restoration of physiological weight. Notably, co-administration of turmeric and ginger (Group C) resulted in the most balanced response, suggesting a synergistic interaction between curcumin and gingerol in modulating oxidative stress responses. This is consistent with earlier findings where curcumin and gingerol were shown to enhance antioxidant enzyme activity and scavenge free radicals (Sharifi-Rad *et al.*, 2020; Zhou *et al.*, 2022).

These antioxidant effects are comparable to previous research where flavonoid- and saponin-rich plant extracts mitigated toxin-induced oxidative damage. For instance, in a study on aluminum chloride-induced reproductive toxicity, *Cyperus esculentus* and *Phoenix dactylifera* extracts significantly restored sperm quality and testicular structure through antioxidant and hormonal modulation (Agim*et al*., 2025a). Similarly, in a related study, the combination of these extracts preserved prostate histoarchitecture against aluminum-induced hyperplasia by enhancing tissue resilience through antioxidative pathways (Agim *et al.,* 2025b).

Furthermore, our findings resonate with research involving *Heinsia crinita* and tender coconut water, where treatment effectively attenuated scopolamine-induced neurodegeneration by lowering MDA levels and enhancing GPx activity (Isamoh *et al*., 2024). Such similarities reinforce the proposition that polyphenol- and flavonoid-rich natural products exert therapeutic benefits in models of oxidative damage via modulation of redox-sensitive enzymes and cellular repair mechanisms.

Also noteworthy is the study involving myricetin in MNU-induced oxidative stress, where myricetin treatment significantly reduced CAT and SOD perturbations and improved adrenal gland histoarchitecture (Umoh*et al.*, 2024). These results complement our current observations that antioxidant interventions can preserve systemic physiological functions and tissue integrity in chemically stressed models.

Although the GPx levels did not significantly differ across groups in this study, the upward trend observed in turmeric and ginger-treated groups may indicate a subthreshold therapeutic benefit, possibly due to duration or dosage factors. This is analogous to findings in gallic acid-treated diabetic rats, where GPx levels showed mild restoration despite profound changes in other markers (Isamoh*et al*., 2025c). Thus, prolonged or higher-dose interventions might be required for full restoration of this enzyme system.

Body weight assessment in the present study served as a physiological indicator of systemic toxicity and recovery. Cadmium exposure resulted in a statistically significant weight loss, likely reflecting anorexia, metabolic impairment, or tissue damage. Treatment with turmeric and ginger prevented this decline, particularly in the turmeric-only group, which maintained baseline weight. This supports existing literature on the metabolic stabilizing effects of curcumin in toxicity models (Ayustaningwarno *et al.*, 2024).

Collectively, our findings support the protective, modulatory role of turmeric and ginger against cadmium-induced oxidative damage, in part through enzymatic restoration and physiological stabilization. These observations are further strengthened by evidence fromStachytarpheta jamaicensis-treated Parkinson’s models, which demonstrated lifespan extension, improved motor behavior, and suppression of oxidative markers—highlighting the conserved mechanisms by which phytochemicals mediate neuroprotection and systemic balance (Isamoh *et al.*, 2024b).

These diverse studies collectively validate the central hypothesis of this investigation: that phytochemical-rich natural products, such as turmeric and ginger, are capable of ameliorating cadmium-induced disruptions in antioxidant balance and physiological well-being, positioning them as promising agents in integrative toxicology and preventive therapeutics.

**4.2 Conclusion**

The current study demonstrated that turmeric and ginger possess significant antioxidant and body weight-stabilizing effects in cadmium-exposed female rats. Cadmium chloride administration resulted in oxidative stress, as evidenced by decreased SOD, CAT, and GPx activities and elevated MDA levels, along with weight loss. Treatment with turmeric and ginger—especially in combination—attenuated these adverse effects, restoring antioxidant balance and improving weight status.

These findings suggest that turmeric and ginger could serve as effective natural interventions against heavy metal toxicity, with broad implications for environmental toxicology, reproductive health, and integrative medicine. Further investigations involving longer treatment durations, varied dosages, and mechanistic evaluations at the molecular level are warranted to validate and extend these outcomes.

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